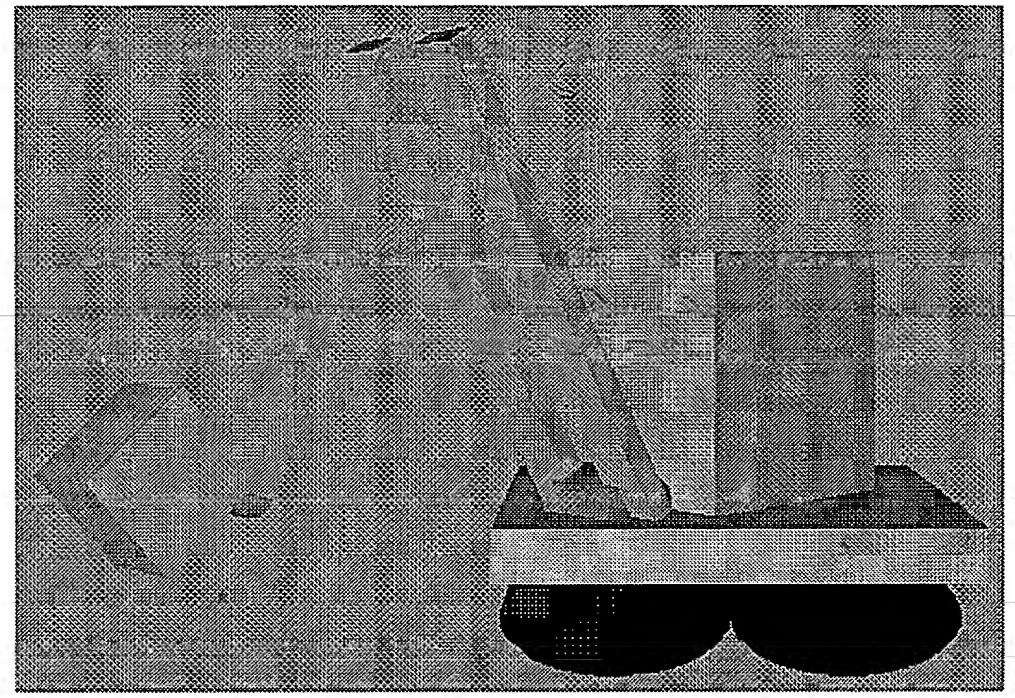
Scientific Visualization Lab

Introduction to Wavefront

This document outlines the use of the basic features of *Wavefront*, a modeling, rendering, and animation package from Wavefront Technologies, Inc. The features are shown through a tutorial in which a sample model, a steam shovel, is built. This tutorial is based on one written originally by Jack Tumblin.



The Steam Shovel

The tutorial below is divided into the following sections:

The Director

The Wavefront package is divided into smaller, specific programs. The *Director* is the program which manages projects and launches these smaller programs. You will probably want to keep your Wavefront files together in a directory like `~/wave`. From this directory, run the director:

```
wavefront
```

You'll get a large window with a thin `Wavefront` panel on the left containing icons for the programs, a small square `Projects` panel with a single `Default` icon, and a lower `Message Panel`.

What we are going to design is a single body (a steam shovel), built out of five rigid-body *model*s. The first thing to do is build the models. Click on the `Model` icon in the Wavefront panel to launch the *Wavefront Advanced Visualizer Model* program (and you'll probably want to iconize the Director).

Model

The Interface

Model (also called TAV for The Advanced Visualizer) can be very intimidating at first, as well as confusing. It's not as bad as it looks, though; we won't need most of the controls you see to design our rigid-body models. The interface is divided into 6 areas:

Main Menu
: The main menu is a list of buttons at the top left-hand corner. These serve the same purpose that normal pulldown menus do. To get the submenus (below the main menu on the left), click on the main menu buttons.

Viewport
: The viewport is the large panel in the middle of the window, with the associated list of controls at the top and below. Operations using the viewport controls affects only how you look at the object (from what angle, how far away) and how it is shown (perspective projection, wireframe rendering, with or without axes). They do not change the object in any way.

Text Port
: The text port is the large box under the viewport controls. It is used for input and output text communication.

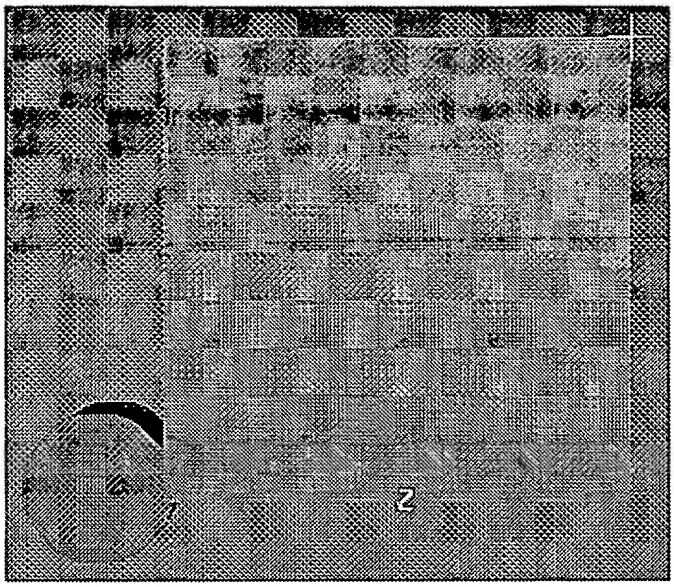
Edit Mode Menu
: The edit mode menu is the 6 items on the right from `Point` to `Regroup Elements`, which indicates which edit mode you are in.

Mode Operations Menu
: The mode operations menu appears above the edit mode menu, and it depends on which edit mode you're in. This will be the menu we'll access the most. It lets you do things like move groups around and scale them.

Edit Controls Menu
: The edit controls are in the lower right-hand corner of the window. They serve as a limited cut-and-paste and undo set of controls.

Rigid-body models are composed of *groups*, which in turn are composed of *elements*. We'll be able to do all of our work at the group level.

Creating the cab



The cab we create here will include the box the operator sits in and the winch. To create it, do the following:

1. Turn on the axes by pressing the `Axes` button under the viewport.
2. Get the `Shapes` submenu by pressing the `Shapes` button in the main menu.
3. Create a cube by pressing `Cube` in the submenu. This creates a group called `cube`, and a wireframe cube should now be visible in the center of the viewport.
4. Our cab will be a bit skinnier than it is long or tall. We need to scale down the cab along the X-axis. Press the `XSCALE` button on the right. You can play around with the scaling by dragging left and right or up and down inside the viewport panel. Note that the rate of change of the `XSCALE` value is related exponentially to how far you drag. Have some fun, and then enter the value `0.8`. It automatically goes into the text port.
5. All rigid-body objects must rotate about their origin. It makes the most sense to position the cab's origin in the center of its base. At present the origin is in the very middle. We can't move the origin, but we can move the group: click on `YTRAN` (on the right; *not* under the viewport) and give a value of `2.5` by typing it in or dragging on the viewport panel. Why 2.5? The default dimensions for the shapes are given in the `Shapes` submenu. They're all 5, and we needed to move the shape half its height. Don't change these default values; the rest of the tutorial assumes they're 5.
6. We're conceiving of the steam shovel with the bucket on the left, and the cab on the right. It's easiest (but not strictly speaking *necessary*) to design each of the rigid-body objects so that they are oriented correctly with respect to each other. The narrow part of the cab is facing us, but it should be facing left/right. To get it facing correctly, we want to turn (rotate) it as if it were held in place by a vertical pole running through it. This kind of rotation is a Y-rotation, since the vertical axis is the Y-axis. Click on the right-hand `YROT` button, and give it a value of 90 (degrees).
7. This group is now in place, so make all of the changes permanent: click on the `Save` button in the bottom right-hand corner of the window. This makes all of the current settings to be the normal ones for the group, so the scale values are `1.0` and the translation and rotation values are `0.0`. It *doesn't* save your work into a file, but we'll do that in a minute.
8. Create a cylinder by pressing `Cylinder` near the `Cube` button. This creates a cylinder, and also makes it the active element group, which is drawn in red.
9. There are some problems with the new cylinder. First of all, it is oriented the wrong way. We want the circle side facing us, requiring a 90 degree X-rotation. Do this now.
10. Secondly, it's much too big. Scale down the entire thing (using the element group's `Scale` button to 0.35.
11. Now we want to slide it to the left so that it and the cube just touch. How much is this? If we've been putting in approximate values on the dials, then we'll only be able to get this approximately correct, which

may be fine, although trying to zoom in on that one spot to examine can be frustrating. Since we've been using exact values, we can calculate it. (Working with wavefront is going to be much easier in general with a blueprint, just like it's easier to create a pretty picture inside a drawing program if you have a sketch made.) The cube extends 2.5 to the left, and the radius of the cylinder is (0.35)(2.5)=0.875. So the cylinder needs to go 3.375 to the left, or an XTRANS of -3.375 (since left is negative in the X coordinate system). If this doesn't look quite right to you, try playing with the viewport's YROT (*not* the group's YROT on the right) to get a better look at the object.

12. Save this group's settings as you've done before with the cube.
13. Now we'll save the object itself. Click on File in the main menu, then on Save in its submenu, and enter cab.obj in the text port.

Setting materials

All of this time we've been looking at these groups as wireframe models, with the active group in red and the nonactive group in green. If you want to see these groups as solid objects, try clicking on the Flat Shading button under the viewport.

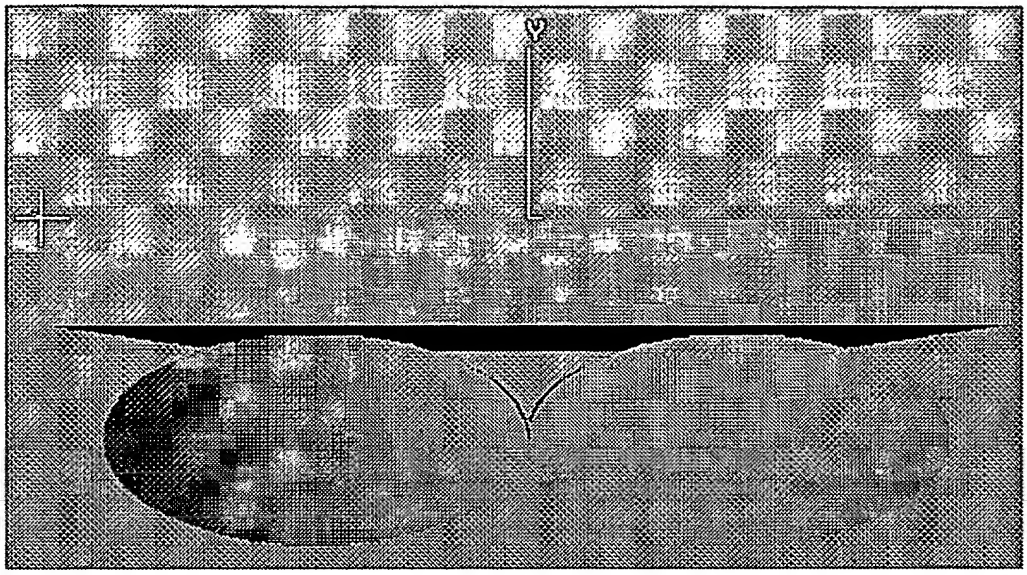
Of course, the color is still wrong. We'd rather have a bright yellow operator's box and a rust-colored winch. Wavefront draws its objects (and groups) using predefined *materials*. Instead of dwelling on material definitions in this tutorial, we'll just use a sample file of material definitions. Save this file in your Wavefront work directory. Then tell Wavefront to use it: click on the Properties button on the main menu, then Material File... on its submenu. Choose the file by clicking on it and then on OK.

Now we can set group materials for our two groups. Click on Group List under the viewport. Click on cube in the new window. Then click on Group Material in the main submenu. Find aocyellow and select it (click on it, then OK). Now select the cylinder group, and change its material definition to iron_oxide (you'll have to use the scroll arrow buttons).

To see the object with its material definitions, click on Material Shading under the viewport. If you're sitting at an Indy or better, you'll be able to rotate the object around (using the viewport controls) and see how the light source affects the way the object looks.

Be sure to save the file again to keep the material definitions.

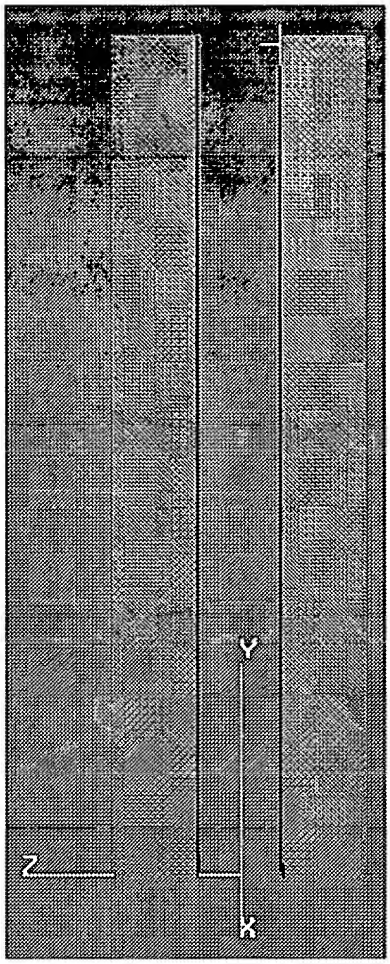
Creating the treads



The treads will be a large, flat platform sitting on a couple of squashed cylinders. Eventually the cab will sit on top of it. We will create the treads with the following steps:

1. Click on `File`, then on `New` in its submenu.
2. Click on `Shapes`, and then `Cube`.
3. It's probably a good idea to turn off material shading while editing objects, so click on the `Material Shading` button to toggle it off.
4. We want the platform larger than the cab and the winch, so scale the group 1.8 along the X-axis and Z-axis, and 0.2 along the Y-axis.
5. Align the top of the platform with the axes by translating the platform down by 0.5 (a `YTRAN` of -0.5).
6. Set the group material to `aocyellow` (you'll have to tell Wavefront about the sample materials file again; it can be different for each rigid-body object you have).
7. Create a cylinder. (`Shapes`, then `Cylinder`)
8. Rotate it towards you 90 degrees. (`XROT` of 90)
9. Squash the cylinder vertically by a factor of 0.5. You'd think this would be accomplished with `YSCALE`, but that won't work. Since the group is rotated, its Y-axis is now sticking out of the screen. It's the group's Z-axis that looks vertical to you now. Since that's kind of bizarre to deal with, realign the group's axes with `Save` (lower right-hand corner), and then squash it with `YSCALE`.
10. We have to fit two cylinders side-by-side under the platform which is scaled up by 1.8, so the whole cylinder needs scaling down by 0.9. (`SCALE` of 0.9)
11. Move it down below the platform. (`YTRANS` of -2.125)
12. Set its position with `Save` again.
13. Give it a group material of `aocblack`.
14. Now we're going to make a copy of this group. Click on `Copy` in the lower right-hand corner of the window. The best indication that something happened is that a new group called `copy` appears in the `Groups` panel in the viewport. It and the other cylinder are occupying the same space, which makes them difficult to distinguish right now.
15. We want to slide them apart along the X-axis. Give one group an `XTRANS` of 2.25, and the other -2.25. (To change which group you're editing, click in the `Groups` popup panel. Note that switching groups executes a `Save` operation on the group you were editing, so don't change groups unless you like how the current one is positioned.)
16. Save the object as `tread.obj` (`File` and then its submenu `Save`).

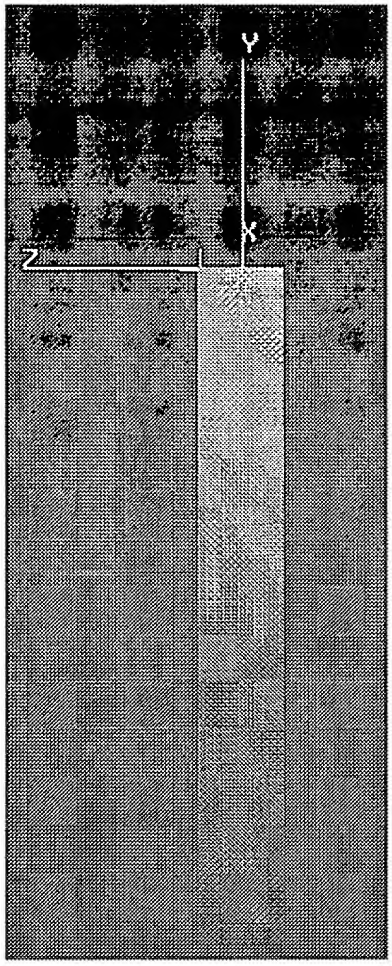
Creating the mast



The mast is the pair of steel beams which extends from the winch and supports the boom. We're going to make each steel beam 0.5x1x10, and leave a gap of 1 between them.

1. Click on `File`, then on `New` in its submenu.
2. Click on `Shapes`, and then `Cube`.
3. Scale the group 0.1 on the X-axis, 2 on the Y-axis, and 0.2 on the Z-axis.
4. Use the viewport's `YROT` to make sure it has more depth than width. Leave the viewing `YROT` at about 90 degrees.
5. Save the group's orientation and position (`Save` in the lower right-hand corner).
6. We want the mast to pivot about its base, so translate it up until the bottom is aligned with the object's axes (set the group's `YTRAN` to 5), and save the group's position again.
7. Set the group's material to `aocyellow` (yes, you'll have to do `Material File...` first again).
8. Copy the group. (`Copy` in the lower right-hand corner)
9. We want to pull the two beams apart along the Z-axis. Normally you wouldn't be able to see this well, since the Z-axis runs out of the screen, but since our view is rotated about 90 degrees about the Y-axis, the Z-axis looks left to right to us. To pull them apart, enter a `ZTRAN` of 1 for one and -1 for the other.
10. Save the object into `mast.obj`.

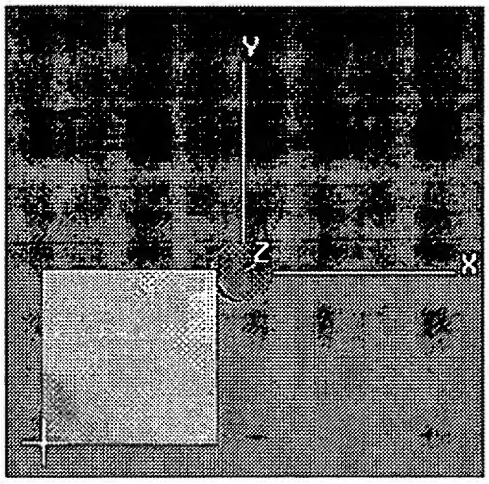
Creating the boom



From here it gets really easy; we're going to cheat and reuse the work we've already done. Don't press `New` to start a new group (if you have, use `Open` under the `File` menu to load `mast.obj` up again). Instead, click on `Save As...` under the `File` menu. Enter `boom.obj`. (We could have done this later, but it's too easy to click `Save` by accident and destroy the mast. This way we're no longer editing the mast but a copy of it we're calling the boom. If you *have* overwritten an object file by accident, look ahead to the section on File Recovery.)

1. First, let's get rid of the copy group. Click on `copy` in the `Groups` panel to make it active, and then click twice on `Delete` in the lower right-hand corner to delete it.
2. Now make `cube` the active group, and translate it along the Z-axis back to the object axes (either 1 or -1).
3. We want the boom to hinge at the top, not the bottom; translate the group down until the top aligns with the axes (`YTRAN` of -10).
4. The boom is not quite as long as the mast; give the group a `YSCALE` of 0.8.
5. *Whoops!* Why isn't the top aligned with the axes anymore? The reason is that the scaling is based on the group's axes, which haven't yet been moved to the top (the same reason `YSCALE` wouldn't squash the cylinders when we made the treads). Undo the scaling damage (enter a `YSCALE` of 1, or click on `Init Chan` to restore the setting). Now `Save` the group's position to move its axes (lower right-hand corner). Now try the `YSCALE` again.
6. Now save the boom with the `File` menu's `Save`.

Creating the bucket



We get to cheat again. The bucket looks a lot like a smaller version of an upside-down cab.

1. Load cab.obj using `Open` under the `File` menu.
2. Let's view it from a `YROT` of 0; that's how we're using to seeing the cab (the viewport `YROT`, *not* the group's `YROT`).
3. Before we forget, save this object file as `bucket.obj` (`Save As...`).
4. We want the bucket to hinge about the center of the cylinder. To do this we need to move both groups. It would be easy to `XTRAN` each group 3.375, but this is a chance to show off a nice feature of group editing. Everything we've done thus far has been in group editing mode; note the highlighted `Element Group` button on the right.
    1. Now select `Regroup Elements`.
    2. Click `New` (in the lower right-hand corner) and give the group name `all`. Notice `all` is now the active group, but it has no points in it.
    3. Now click on `Group Add All` at the top right. Now you can manipulate the cylinder if `cylinder` is the active group, the cube if `cube` is the active group, or both if `all` is the active group. **Caution**: deleting the group `all` takes all of its points with it. If you decide you don't need the `all` group, take all of the points out of it first with `Group Remove All`.
    4. Select `Element Group` again.
    5. Slide the entire thing over by giving `all` an `XTRANS` of 3.375.
5. Save the group's position.
6. Flip it over with a `ZROT` of 180 degrees. (See, the `all` group is nice.)
7. Scale everything down to 0.4 (use `SCALE` on the right).
8. Save `bucket.obj`.

Congratulations! Your five rigid-body models are now complete. (Wasn't so painful, was it?) The good news is that you're finished with TAV (click on `Exit` under the `File` menu). The bad news is that now you have to deal with:

PreView

In Director, click on `PreView`. "Oh, great! Not another counter-intuitive interface!" you may say. Well, it at least works similarly to TAV in many respects.

It's possible to create our PreView file using `New` under the `File` menu, but that gives you 30 frames, which I haven't been able to change. Instead, click on `Command Line` in the lower left-hand corner of the screen, and

inside the text port (at the pv> prompt), enter `init shovel.pv default 100`. This creates a 100-frame sequence, using the default setup file name `WF_def.set`, which you may view with a text editor. (The PreView file `shovel.pv` created is not a text file.)

To get back into the normal graphics-interface mode, enter `ed`.

The Object List

In PreView, the term *object* refers to rigid-body objects, light sources, and cameras. Click on `Object List` (under the viewport) to get a list of them.

1. We're only going to use one camera, two light sources, and 5 rigid-body objects, so turn off the extra cameras with `Num` (first column) of 2 and 3. Do this by clicking on `ON` in the `Play` column on those rows.
2. Turn off the reflection object and dummy object (objects #6 and #7).
3. Now let's set up the light sources. Like material definitions, we're not going to spend any time discussing the format of light sources; we're just going to use two sample ones, `white.lgt` and `point.lgt`. Click on the `File Name` column for `light1` and select `white.lgt`. Then do the same for `light2`, selecting `point.lgt`. We won't position the lights until we have rigid-body objects for them to shine on.
4. Objects #8-#12 will be our rigid body objects. Of course, we only have 9 available now. So click on `Num` for object #9, then `Copy` (above the object list), then `Paste` three times (this operation is a little slow; be patient).
5. Make object #8 the treads by changing its `Name` to `tread`, and selecting its `File Name` as `tread.obj`.
6. Make object #9 the cab similarly. One extra thing, however: the objects are structured *hierarchically*, which means they have *parents* and *children*. When a parent moves or rotates, its children move and rotate with it. They may move one their own, however. Think of it as passengers in an airplane. The airplane is the parent, and the passengers are the children. When the airplane moves, it takes the passengers with it, but the passengers may also move around. In this sense, the treads and platform object is the parent of the cab, which then is the parent of the mast, which is the parent of the boom, which is the parent of the bucket. So to make `tread` the parent of the cab, choose the `Parent` column for the cab, and select `tread`. (You can even make cameras and light sources children of objects so that they follow them around.)
7. Make object #10 the mast, and make its parent `cab`.
8. Make object #11 the boom, and make its parent `mast`.
9. Finally, make object #12 the bucket, and make its parent `boom`.
10. Objects are color coded for editing. Pick any nice set of colors for the objects that you want, preferably without reusing a color. The controls for each object is color-coded on the right. (Pick rigid-body colors first, then the main camera, then the light sources. Don't bother with the 4 objects which are `OFF`.) My personal color scheme is:
    - `maincam MAGENTA`
    - `light1 WHITE`
    - `light2 BLACK`
    - `tread RED`
    - `cab BLUE`
    - `mast GREEN`
    - `boom YELLOW`
    - `bucket ORANGE`
11. Close the object list by clicking again on `Object List` under the viewport.

Positioning the camera

Doesn't look like much, does it? Don't panic. The viewport is showing the view of the active camera (object #1), which is positioned inside everything else. To fix it, choose the ZTRAN dial for object #1. (The 1/3 notation refers to object 1, control 3, which just happens to be ZTRAN.) A value of about 35 should do. And for good measure, give it a YTRAN of about 5.

Assembling the steam shovel

The cab is fine, but the mast needs to come out of the winch. Give the mast (object #10) an XTRAN of -3.375. You'll have to use the Up and Down buttons on the right, and they seem to work backwards for some reason. Notice that when you move the mast, you automatically move its child (the boom) with it, which moves *its* child (the bucket) with it. Next, the boom (object #11) needs to come up and hinge at the top of the mast. A YTRAN value of 9.75 will work well (10 would put it at the very top, but there needs to be overlap through which the pin would go on a real steam shovel). Finally, the bucket (object #12) needs to slide down the length of the boom (YTRAN of -8).

Still doesn't look like much? Try giving object #10 (the mast) a ZROT of about 30 degrees. Then give object #11 (the boom) a ZROT of about -45 degrees. Finally! It looks like a steam shovel!

Positioning the light sources

Click on Material Shading. Everything seems dark because the only light sources are inside the platform. Position objects #4 and #5 where you like them. You may try these parameters, but you don't have to use them:

- Object #4 YTRAN = 10
- Object #4 ZTRAN = 30
- Object #5 XTRAN = -10
- Object #5 ZTRAN = 20

(These positions do have the added advantage that the arrows which indicate the light positions are completely off camera.) Now click on Savekey in the lower right-hand corner. That'll make your control changes for this frame permenent. If you don't do it, you might easily one or more of them when you change the controls menu in the next section (and you'll have to reassemble the steam shovel).

Simplifying the task

All of our care in setting up the rigid-body models was to make the animation easy and to remove the need for most of the controls. The only controls we need are the ones we've used already to position the camera and light sources (since they're positioned only on frame 1) and the controls needed for the steam shovel itself:

- tread XTRAN
- tread YROT
- cab YROT
- mast ZROT
- boom ZROT
- bucket ZROT

So we're going to take most of the controls off of the menu to the right (we can always put them back again). Pull up the object list.

1. Select the Edit field of the main camera (object #1). Unhighlight any controls whose values are 0 on the right, and then click on OK.
2. Do the same for both lights.
3. Select Edit for the treads. Unhighlight everything except for XTRAN and YROT, and click on OK.
4. Select Edit for the cab. Unhighlight everything except for YROT, and click on OK.
5. Select Edit for the mast. Unhighlight everything except for XTRAN and ZROT, and click on OK. (You may be wondering why we're keeping XTRAN if we're not going to change it. The reason is that PreView's method of copying frames only copies the control values currently active. So any change from the default setting which you want propagated needs to stay open also.)
6. Select Edit for the boom. Unhighlight everything except for YTRAN and ZROT, and click on OK.
7. Do the same for the bucket.
8. Close the object list.

Good! A much more manageable set of controls, and we don't have to mess with Up and Down anymore. This is a good time to save your work: click on Save under the File menu.

Animation

The set of controls describes the placement the steam shovel as you want it in *one* frame. Now I know what you're thinking: "Um, don't we have *100* frames in this animation?" Yes we do, but we can do the 100 frames by setting up *key frames* along the way and letting PreView interpolate to fill in the missing frames.

You're always editing one of your frames. Look below the viewport controls. There's a long bar with Begin and End at the ends. Below it there's the frame range. A thin pink line rests on frame 1; that's what frame you're editing now. If you click on that line to view another frame, you'll see it's the unassembled steam shovel with the camera and lights at the origin. Get back to frame 1.

We're going to try a very simple animation that has four components:

1. The steam shovel rumbling in from the right. (30 frames)
2. The cab swinging the mast, boom, and bucket out towards the user a little. (20 frames)
3. The mast and boom lowering the bucket. (25 frames)
4. The bucket scooping. (25 frames)

Frame 1

1. Set the mast's (object #10's) ZROT to about 30.
2. Set the boom's (object #11's) ZROT to about -55.
3. Set the bucket's (object #12's) ZROT to about -25.
4. Use the tread's XTRAN to move the cab to the right side of the screen (or off the screen, if you prefer).
5. Click on Savekey.

Frame 31

1. Advance the frame to 31 by clicking there on the frame range or by using the frame controls above it. You can also click on Goto Frame in the viewport controls and enter 31.
2. Move the steam shovel back to the origin (set the tread's XTRAN to 0).
3. Click on Savekey. Notice that the number 31 now appears in the frame range.

Frame 51

1. Advance the frame to 51.
2. Turn the cab towards the user about 45 degrees (cab YROT of about 45).
3. Click on Savekey.

Frame 76

1. Advance the frame to 76.
2. Lower the mast and boom so that the bucket approximately touches the "ground". Setting just the mast's ZROT to 40 does this pretty well.
3. Click on Savekey.

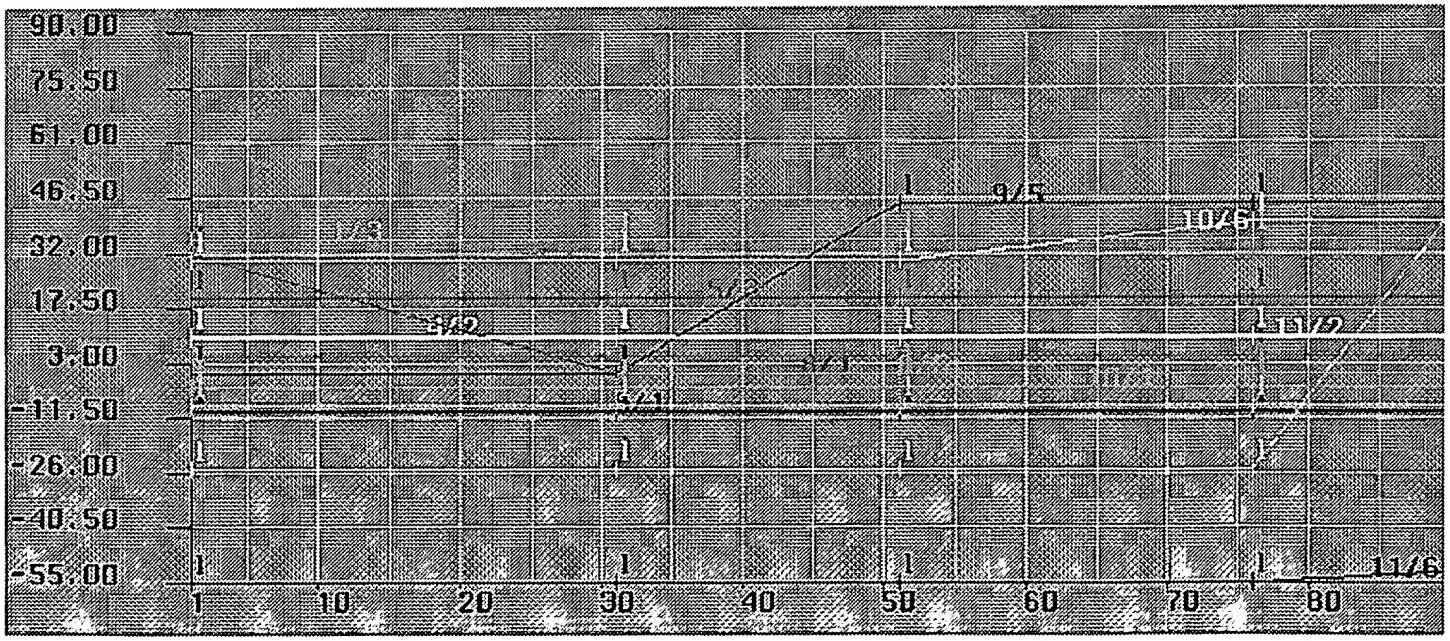
Frame 100

1. Advance the frame to 100.
2. Pull in the boom slightly (set its ZROT to about -50).
3. Scoop the bucket in (give it a ZROT of about 90).
4. Click on Savekey.

Now, before we do any interpolation, let's do ourselves a favor and Save the file. Be aware that this will save your frames, but it doesn't mark them as keyframes. If you mess up the interpolation and load your file in again, you'll need to go to those frames and mark them as keyframes before interpolating.

Interpolation

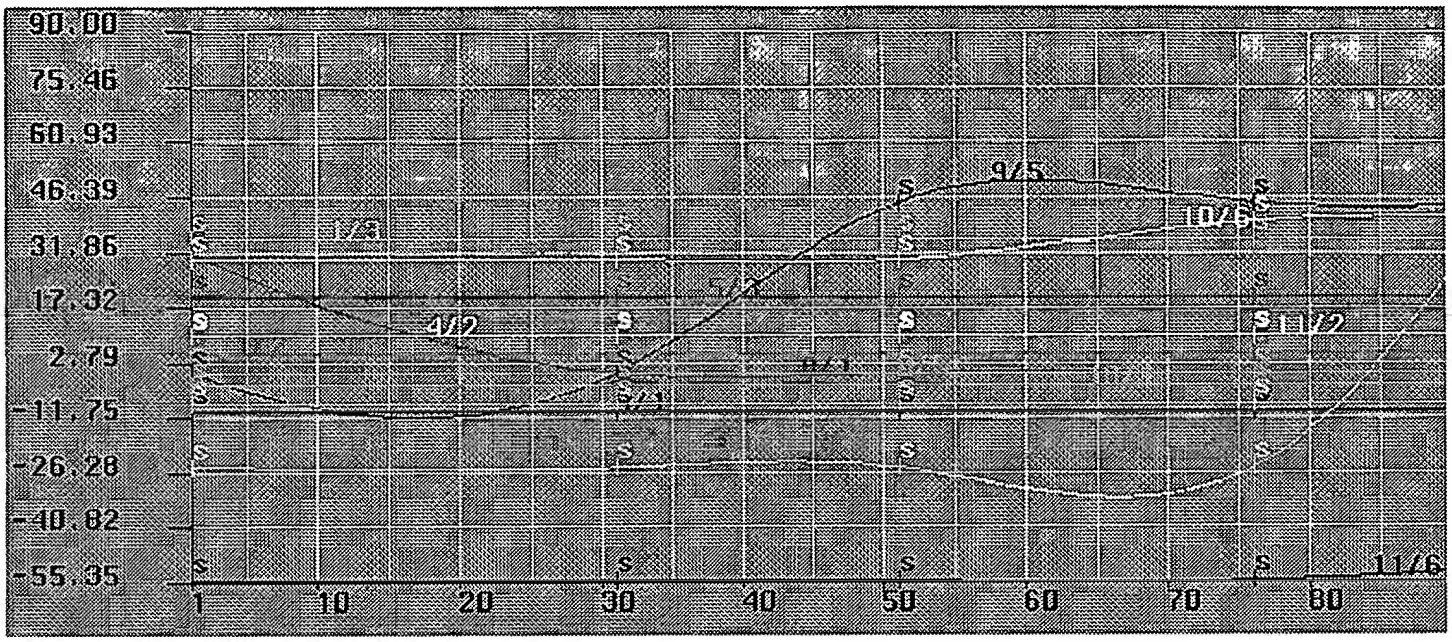
Click on the main menu Create button. Then select Linear. This creates a linear interpolation between your keyframes. In other words, for each control (Y) you have only specified 5 frames (X). PreView connects these 5 sample points with straight lines:



Linear Interpolation

Let's see what this looks like: click on `Pb` (Playback) on the frame controls bar.

Kind of impressive, isn't it? Of course, it *is* a little jerky. Steam shovels don't stop on a dime. Click on `Spline` now. A *spline* is a polynomial curve through the sample points, usually cubic. It eases the rigid feel of linear interpolation, but occasionally introduces strange anomalies. A 2-D path interpolated with splines, for example, may acquire loops which wouldn't appear with linear interpolation.



Spline Interpolation

Let's see the new animation: `Pb`.

Smoother, but now we have the problem where the steam shovel drifts a bit. That's because the curve has to make a smooth transition; the steam shovel can't just stop there. Fixing this kind of thing is a real problem in practice, although in theory you may make adjustments directly to the interpolation graph. Click on `Graph`. Try grabbing individual points and dragging them. The update happens in the viewport at the same time. You can interpolate again and see the changes in the graph. When you're finished with the graph, press `Esc`.

And that's all there is to it. Embellishments might be nice, such as a rigid-body object for the earth that the bucket scoops into, and making the bucket hollow instead of solid, but it's not a bad first start. Give yourself a pat on the back.

Appendix

File Recovery

Every time you save a file in Wavefront, it automatically makes a backup for you. For rigid-body object files, the name of the backup is a comma plus the name of the file. For example, `",tread.obj"`. For PreView files (with the `".pv"` extension), two commas come first; for example, `",,shovel.pv"`. You can manually restore the older version from the system prompt using `mv` (e.g., `"mv ,tread.obj tread.obj"` or `"mv ,,shovel.pv shovel.pv"`).

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